MRPP : the French prevention procedure to manage post mining hazards

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MRPP: The French Prevention Procedure to Manage Post-Mining Hazards

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Abstract

Even if most French mining sites are definitively closed, potential risks remain above the abandoned exploitations. Those risks influence the land use management of post-mining areas. In order to manage properly those risks, French State has developed a technical and regulatory tool: the MRPP (Mining Risk Prevention Plan). MRPP aims to identify the most sensitive areas subject to "post mining hazards" and to define regulations able to manage future urbanism development on surface. The present paper proposes a methodological description of MRPP in order to explain the nature and objectives of the procedure.

1 Introduction

Since a few decades, mining industry, which has been during a long period a powerful industrial activity in France, has progressively decreased. Today, most mining sites are closed down but the potential occurrence of hazards and disorders on surface have not definitively disappeared. ln addition to potential ground instability phenomena (subsidence, sinkholes, etc.), some mining sites may be affected by dangerous gas emissions, flooding events or environmental degradations. These effects can occur as soon as the mining extraction stops but also, in certain circumstances, long time after closure.

These phenomena may have major consequences for people, activities and property located on surface in the mine surroundings. They are also likely to have a major influence on regional development in mining areas.

In order to evaluate, post and manage properly those hazards and risks, French Authorities have developed a technical and administrative tool: the MRPP (Mining Risk Prevention Plan). Those Plans are intended to identify the sectors most likely to develop risks in the long term and draw up rules for managing land use according to the various post-mining constraints.

The present paper gives a brief account of the principles supporting the drafting of MRPP, with respect to both administrative procedure and technical requirements of risk evaluation. It is illustrated through a few examples of MRPP elaborated by INERIS during the last 5 years.

2 The MRPP, a tool for risk prevention management

2.1 The MRPP in French Risk Prevention Policy

In France, it is the State responsibility to evaluate hazards and risks as well as to be sure that the information is transmitted and available to citizens. Concerning post-mining hazards, French **law n° 99-245,** of 30 March 1999, set up the Mining Risk Prevention Plans (MRPP).

The main purpose of MRPP is to take risks into account within land-use management (Didier et al., 2005). MRPP procedure is usually requested in sectors exposed to high levels of risk. However, it can also be implemented, as a preventive measure, within zones which may constitute a risk in future and, therefore, in zones where urban development must be limited to avoid an increase of existing risk level. Thus the MRPP process is mainly focus towards the future, through the idea of "prevention".

MRPP identifies zones, which are directly or indirectly exposed to risks, by taking into account the nature and level of risk. Within these zones instructions based on town planning and construction regulations are defined. They have to be applied to each building project, concerning new installations as well as existing properties and activities.

MRPP is a powerful regulatory tool appended to Local Urbanism Plans (established in each French town). It systematically takes priority if the two documents are not fully compatible. There are also many administrative tools assuring the MRPP regulation implementation, starting with penal sanctions in case the rules are not applied.

2.2 Administrative procedure for drafting a MRPP

The Prefect, as the Regional State representative, initiates the MRPP procedure via a "prescription order". This order defines the geographical extent covered by the study and the nature of risks involved. The prevention procedure is applied, as far as possible, to global physical units, called "risk basins" defined by natural parameters and/or operations but not by administrative limits (city border, concession limits).

All town councils in the communities geographically concerned are systematically requested to give their opinion during the MRPP elaboration. When the process is finished, the Prefect also submits the draft plan to a public consultation among the populations concerned.

At the end of this consultation the MRPP is approved by a Prefect order. The regulations defined take precedence over the Local Town Planning plans drawn up by town councils.

2.3 The main phases of drawing up an MRPP

As shown if figure 2, an MRPP is elaborated in four main stages.

The data collection phase is designed to collect all available information (including further investigations if they are strictly necessary). It requires an on-site investigation and consultation of archives. This phase ends with the production of an information map, which is of first utility for diffusing essential information among the population (figure 1). This map helps to justify the prevention procedure undertaken by summarising the disorder and harmful effect, which have already affected the site in the past.

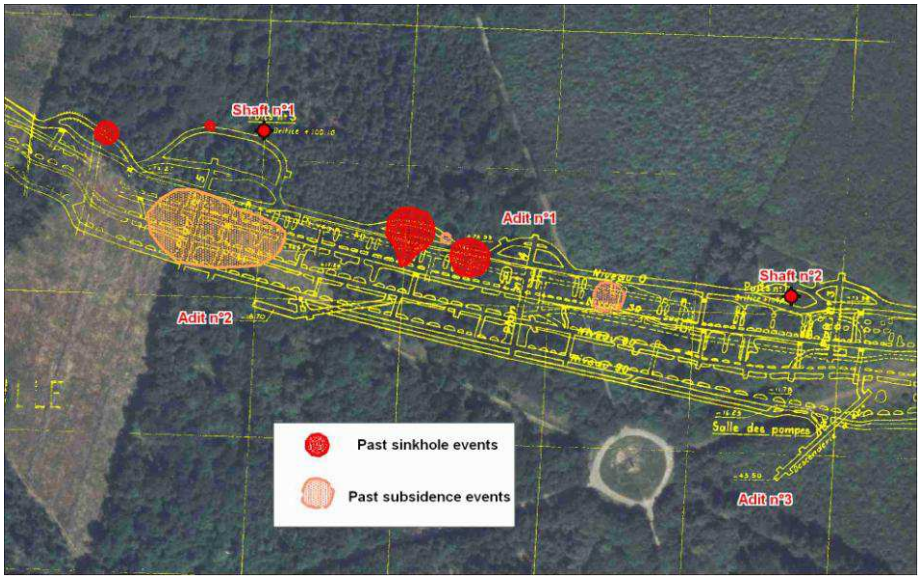

Figure 1 Example of an information map.

The hazard assessment stage is intended to locate the sectors exposed to potential phenomena according to the magnitude of the predictable events as well as their predisposition to development. A hazard evaluation does not take into account surface occupation. The objective of this stage is the drafting of maps locating hazard zones identified by the assessment process.

The stake assessment stage includes drawing up an inventory of all existing stakes in hazardous areas and identifying the potential future projects, which may develop as a result. It is used to identify the population subjected to a non-zero risk level. In particular, it is required to list the most sensitive equipment or public establishments. It results in the production of a map including all the stakes concerned.

The regulatory zoning phase defines homogeneous zones in terms of prohibitions, obligations or recommendations concerning land use, for both new and existing projects. The principle of this zoning is particularly based on the confrontation between the hazardous levels previously identified and the assessment of existing and future stakes characterising the surface. A set of rules is drawn up which is directly linked to this zoning. It is intended to define, clearly and operationally, the regulatory measures, which apply to each regulatory zone.

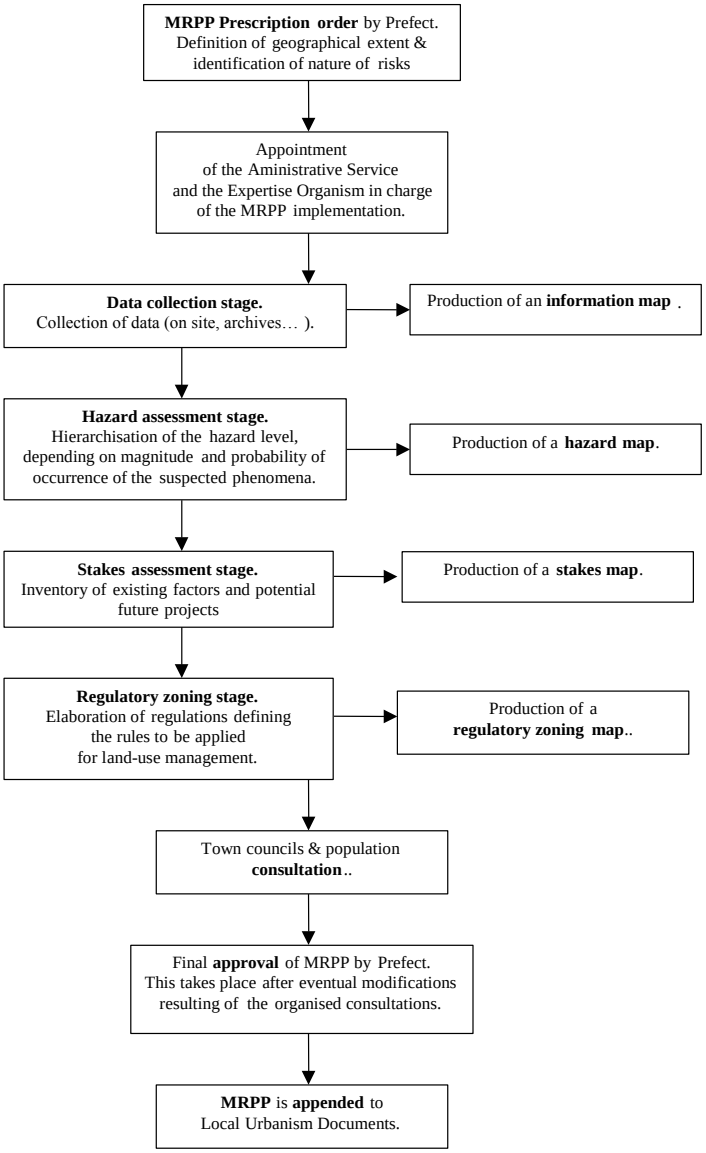

Figure 2 Simplified diagram of the main stages of a MRPP implementation.

3 Identifying, listing and mapping hazards and stakes

3.1 Principles for identifying and mapping hazards

3.1.1 Definition

A hazard corresponds to the probability that a given phenomenon will develop on a given site during a reference period, reaching a quantifiable magnitude. Characterising a hazard is therefore usually based on the **predictable magnitude of the phenomenon** with its **probability of occurrence.**

The **magnitude of the phenomenon** corresponds to the amount of disorders or harmful effects likely to result from the feared phenomenon. This notion includes both quantification of the consequences of the feared events (i.e. size of a crater) and the potential severity of their effect on people or goods (possibility of victims or damage, existence and/or cost of prevention measures, etc.).

The **probability of occurrence** reflects a site's sensitivity to be affected by any of the analysed phenomena. This is a concept, which is particularly difficult to quantify considering the complexity of the triggering mechanisms, the heterogeneity of the rock mass and the very partial information available. Therefore, within the context of post-mining hazard assessment, priority is given to the notion of a site's **predisposition** to suffer future disorders. Evaluation of this predisposition depends on the combination of several parameters, which are favourable or unfavourable to the initiation and development of the identified mechanisms.

3.1.2 Qualification of magnitude and predisposition classes

The magnitude of the phenomenon characterises the amplitude of the expected consequences if the feared event takes place. Each type of phenomenon has one or more corresponding representative physical values, which can be used to characterise the consequences of the feared events. It is therefore, for example, the size of craters which defines the intensity of sinkholes.

To evaluate the magnitude of the feared phenomena, the expert attempts to evaluate, often approximately, the expected value of the parameter judged to be representative. Regarding to reference values defining the main magnitude classes, the expert can then define the class to which the feared phenomenon belongs within the relevant context.

These reference values have been defined in the framework of a methodological guideline dedicated to the MRPP drafting. This was done under the scientific co-ordination of INERIS, a French Public Expertise Body in, charge of assessment of risks related to industrial activity.

The suggested reference values are provided for information and can be adapted to a specific context by the expert in charge of risk assessment. The main interest of this “reference values” step is to contribute to enable a homogeneous approach at a national level. This limits indeed the subjectivity of the analysis inherent to the sensitivity of each expert.

As an example, the following table shows the magnitude classes of the phenomena representative of different classes of disorders.

Table 1 Magnitude classes defined by reference threshold values

Magnitude classes	Flooding	Surface instability
	Discharge modification (flow rate in dm^3/s).	Diameter of crater left by sinkholes
Limited	Seepage (< 1)	Ø < 3 m
Moderate	Small stream (< 10)	3 m < Ø < 10 m
High	Large stream	Ø > 10 m

Determining predisposition is first based on an experience feedback analysis taking into account disorders or harmful effects having already affected the site (or a similar site) in the past. The assessment is also based on the analysis of scenarios and mechanisms, which may trigger phenomena likely to affect surface land. For example, a very thick overburden, small-scale residual voids and presence of strong layers in the overburden will make this site less predisposed to sinkholes in comparison with shallow mining works located under a "marly" overburden.

Predisposition assessment is often complicated by lack of information available especially in very old mining works. It may then appear necessary to manage such a lack by using the concept of "presumption".

3.1.3 Hazard assessment principles

The principle of hazard qualification consists of combining criteria used to characterise the intensity of a feared phenomenon with the criteria used to characterise the predisposition class. Several principles, explicit or implicit, can be used to combine qualitative values with quantitative criteria.

Nevertheless it has to be noticed that MRPP has been conceived to evaluate hazard and risk levels, at the state of knowledge and according to the expert judgement. Hazard assessment methods consist thus generally of qualitative approaches based on the available data collected on site or from archives. This choice aims to privilege relatively rapid and not too costly hazard assessment studies. The scope is to make MRPP possible in a reasonable time and cost above the most alarming abandoned mines in the view of public safety.

In terms of assessment methods, when the cross-referenced table principle is selected, a synthesis matrix is used as it is done in table 2. To avoid complicated restitution maps, it is usually suggested to limit, as far as possible, the hazard levels to three classes: low, moderate and high hazard level.

Table 2 Example of hazard assessment method based on cross table (magnitude vs predisposition)

Predisposition / Magnitude	Very low	Low	Moderate	High
Very low	LOW HAZARD			
Low				
Moderate		MODERATE HAZARD		
High				HIGH HAZARD

Hazard assessment quality is often strongly correlated with the amount and quality of available data. Visits of old underground mining works are usually of first interest to recognise the mining configuration as well as the failure mechanisms affecting the mining structures (figure 3).

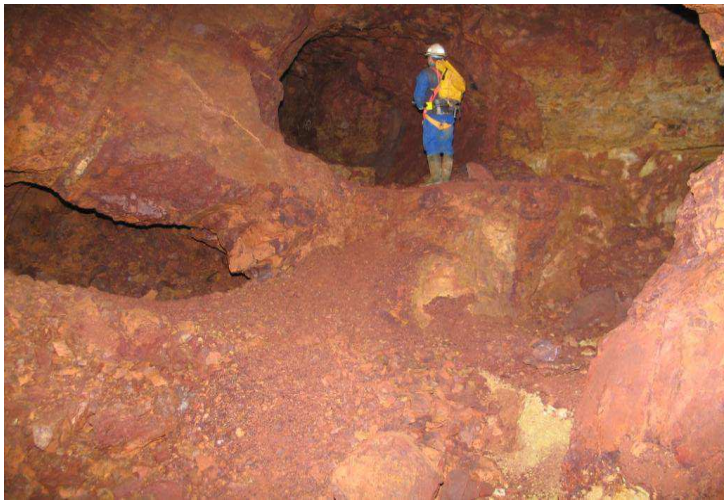

Figure 3 Visit of abandoned underground mining works in iron ore field of Normandy

Unfortunately disused underground mining works are often no longer accessible in safe conditions (mine openings closed, unstable galleries, presence of water and/or gas). The hazard assessment process must thus be operated on the basis of the only available data (old maps, mining reports).

This inevitably results in a certain uncertainty in zoning, which may sometimes be important. This uncertainty margin can, in certain cases, be reduced thanks to the complementary investigations or analyses. Such investigations are to be considered case-by-case, according to the complexity and the danger of the studied phenomena as well as the sensitivity of surface occupation. It is also necessary to evaluate the time requested for these works.

If necessary, some investigations may be undertaken to characterise and/or locate old mining voids (drillings, geophysical methods) in sectors where sensitive stakes are present (cities, infrastructures).

In the same way, the complexity and danger of certain configurations may require to develop numerical models reproducing, as accurately as possible, the rock behaviour. Such analyses were carried out to evaluate the risks associated with a continuous or discontinuous subsidence above major French mining fields: iron ore basins of Lorraine (Fougeron et al., 2006) and Normandy (Renaud et al., 2005), coal basin of Provence (Didier et al., 2003).

3.1.4 Hazard mapping

The hazard has to be mapped for the whole sector concerned by the MRPP so as to demonstrate which sectors are most likely to develop risks or harmful effects. A scale of 1/10 000 is often used to reach a satisfactory compromise between MRPP principles (small scale) and communities requirements (large scale).

The hazard zoning contours are based on technical parameters (geology, operation, etc.). They therefore have no reason to follow the contours of the land plots. When, as it is often the case, several potential phenomena coexist on the same plot, the powerful tools of Geographical Information Systems (GIS) are very performing.

Hazard mapping includes surface areas concerned by the possible effects of phenomena resulting from mining activities. It therefore takes into account the possible lateral extension of disorders or nuisances initiated in underground spaces and developing towards the surface. It also includes the uncertainties associated with the available geographical information (figure 4).

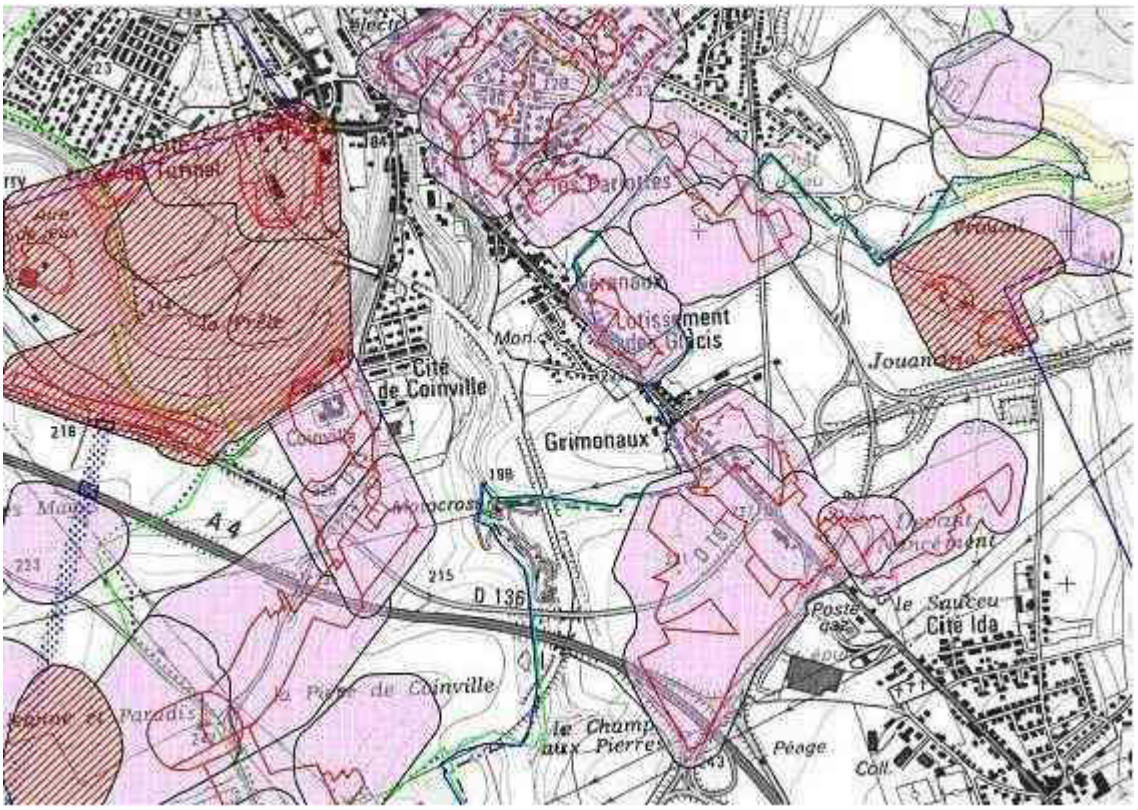

Figure 4 Example of a hazard map in the Lorraine iron ore field (North-East of France)

3.2 Principles of assessing and mapping the stakes involved

3.2.1 Stakes assessment phase

The procedure for assessing stakes involved in mining risks consists of identifying the main types of land occupation or activities, both existing or future, which are likely to interfere with the risk prevention procedure. The major stakes concerned will naturally include urban sectors where the regulatory measures to be applied may differ from those defined for non urbanised sectors.

Assessing all the stakes concerned also includes evaluation of endangered people and listing the main stakes related to safety, crisis management and vital functions in the area. Therefore public establishments, particularly the most strategic in terms of emergency aid organisation (schools, hospital, etc.) are identified. Sensitive equipment (roads, electricity, gas, phone, etc.) are also listed. Traffic roads which must be secured in priority to facilitate public assistance are of first importance.

3.2.2 Stakes mapping

The stakes map (figure 5) is produced at the scale selected for drawing up the MRPP (often 1/10 000).

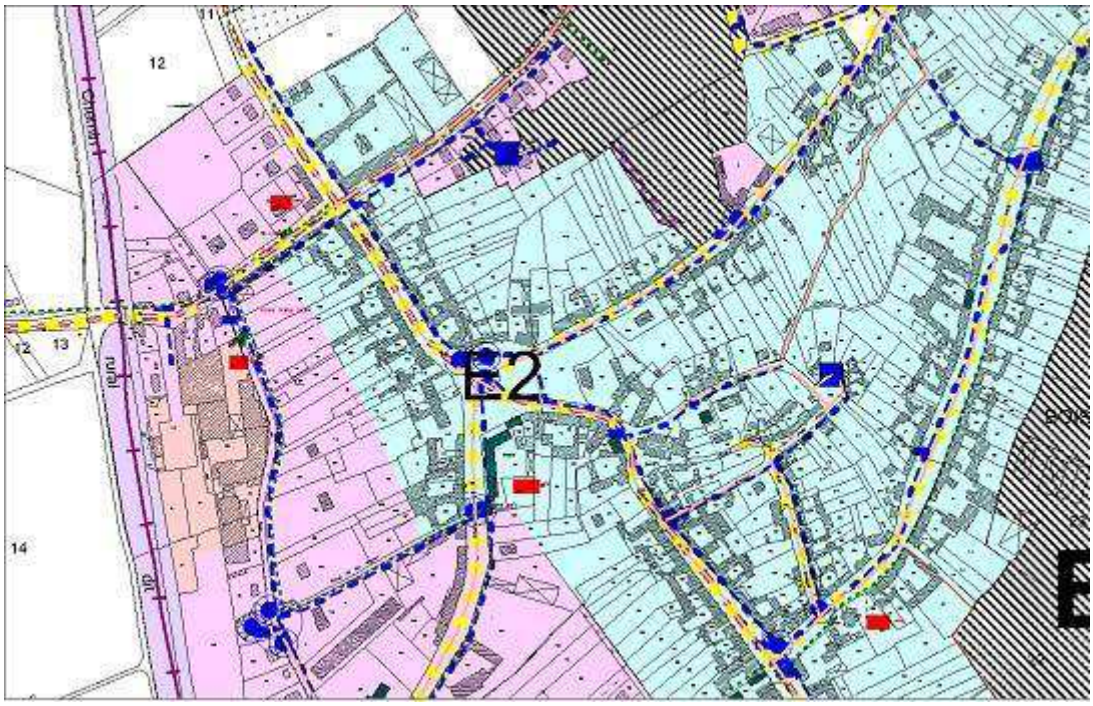

Figure 5 Example of a stakes identification map above an undermined town (North of France).

Depending on the different objectives (personal safety, future urban development, etc.), a few maps can be drawn up giving priority to the most concerned stakes.

4 Drawing up the zoning plan and regulations

4.1 Principles for regulatory zoning

Posting hazard and drawing up a regulatory zoning plan are two specific procedures with fundamentally different objectives. Whereas the first identifies the different types of disorder likely to develop on the surface and locates them, the second marks out the limits of the zones where homogeneous instructions can be defined to ensure the safety of existing and future people and property.

The zones are marked out by cross-referencing hazard and stakes maps, i.e. by combining the type and intensity of a predictable disorder with the occupation of surface land. In general, definition of the different zones is based on constructibility criteria (zones where no building is allowed, areas where building is permitted under certain conditions, etc.). As for hazards, the aim is to avoid multiplying the number of zones, to facilitate the legibility of the maps. For this purpose, the number of zones selected must be limited to three or four. One uses generally a white zone for which the requirements are minimal or non-existent, a red one for the sectors where building is forbidden and one or two blue zones in which urbanisation remains possible but with more or less severe constraints and restrictions (figure 6).

Generally speaking, priority will be given to the development of new urban areas in non risky zones. However although this rule can be applied relatively strictly for areas not yet urbanised, constraints may be relaxed locally in urbanised areas with strong constraints due to mining-related risk over a major part of the area occupied by the communities in question. In this case, building permits may be envisaged in low or moderate risk zones. The regulatory zoning plan must be drawn up, as far as possible, at a scale compatible with studies of risk and stakes assessment phases.

4.2 Drawing up the regulations

At the same time as the zoning regulations are drawn up, the State Department in charge of drafting the MRPP draws up the regulation which defines the regulatory provisions applied to each zone within the regulatory zoning area. These measures are mainly intended to improve the safety of people and property in the zones subject to mining risks. They prevent increasing vulnerability of property and activities in the most exposed zones.

The regulations must be as simple and operational as possible to make it easier for the public to understand and assimilate them. It is generally presented by the type of regulatory zone (red, blue, white) after defining the general measures applied to all the plots in the limit of the MRPP (figure 6).

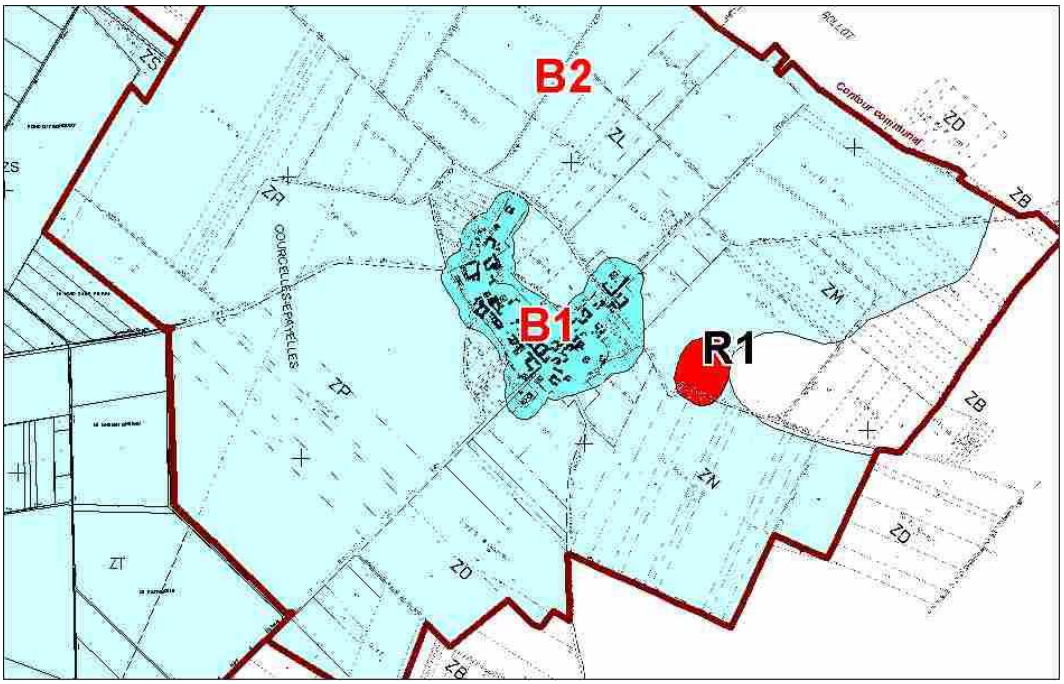

Figure 6 Example of a regulatory zoning map above an undermined town (North of France).

For each zone, it is usual to organise the measures in two groups: those dealing with existing properties and those intended for future projects. The different measures may take the form of prohibitions, obligations or simple recommendations.

One has to notice that one of the regulatory specificity of MRPP, which makes this tool powerful, is the retroactivity that is to say, that measures can be applied to an existing property prior to MRPP. However, if there is no restriction for future projects, the measure imposed to the property built prior to MRPP approval can only lead to some limited changes, costing less than 10% of the market value of the property before the risk was posted.

For a successful drafting and application of the MRPP, all available expertise (administrative, technical and political) must be federated. Regular discussions and meetings are therefore requested between the State Departments and local authorities, to facilitate understanding, appropriation and participation of local authorities in the risk prevention policy.

It is therefore essential to obtain the participation of local representatives when drawing up the regulatory zoning plan and regulations because they are the main authorities in charge of application and in direct relation with the population.

5 First experience feedback

5.1 Work Progress

Since MRPP creation in 1999, more than forty abandoned mining sites located throughout French territory have been studied on the basis of MRPP procedure (figure 7).

To these sites, one has to add the whole Lorraine iron ore field whose analyse has been initiated before MRPP introduction. For this basin, about a hundred under-mined cities have been analysed producing hazard and risk maps.

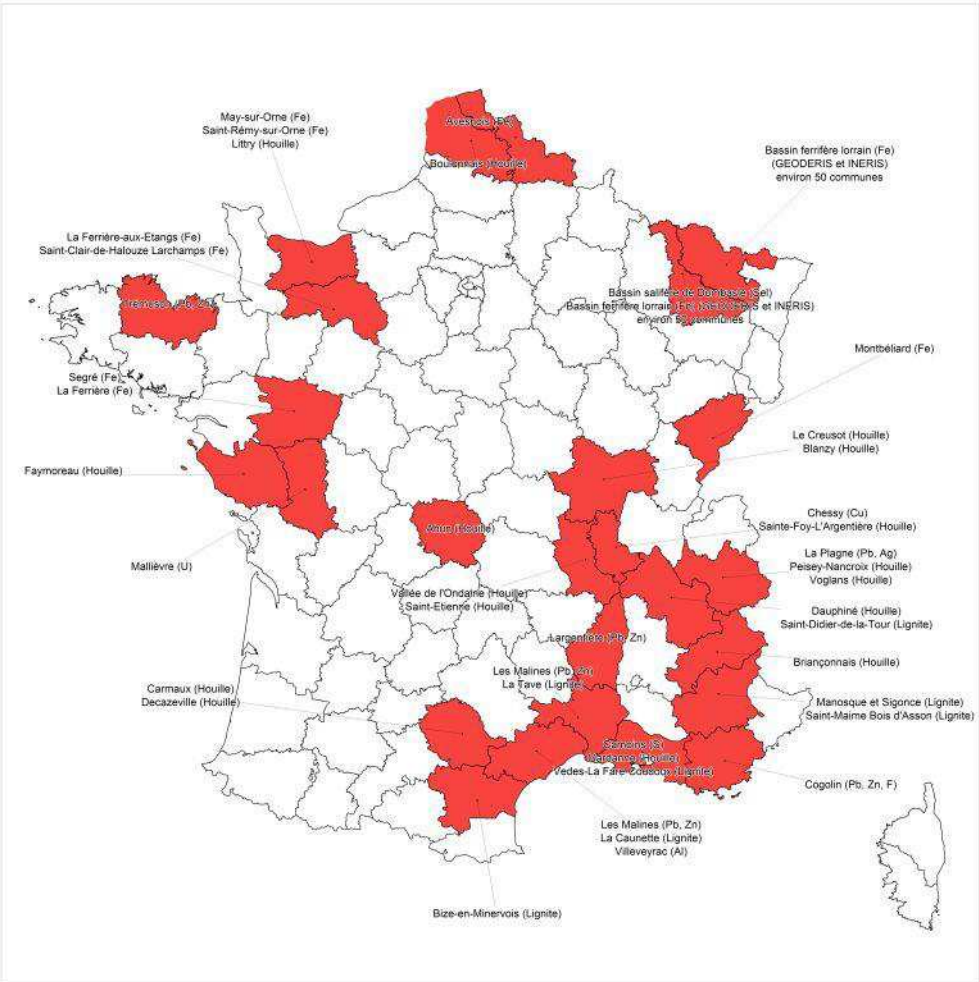

Figure 7 Location of the abandoned mining sites, where MRPP have been implemented.

The MRPPs implemented have concerned the main mining ore exploited in France. One may quote metal mines (lead-zinc of South-Centre and Brittany, copper in the Alps, uranium in Centre-West, etc.), major iron ore fields (Lorraine, Normandy) and many coal basins (Provence and Centre-South…).

The next important step of MRPP implementation will be the major salt basins (Lorraine, Jura, South-West). The beginning of the studies is planned for 2008.

Until now, the great majority of the studied sites concern the "surface instability" hazard. Among those instabilities, the sinkhole phenomenon is of the first importance. It is related to shallow abandoned mining works (few tens metres deep) as well as the sectors highlighting many mine openings (shafts, adits, etc.).

Although generally less sensitive, hazards related to mine gas emission has also been highlighted in many abandoned mining sites (Tauziède et al., 2002). Much more punctually, "environmental hazards" have been identified in some unfavourable contexts mainly resulting from the exploited ore (lead, zinc, silver, etc.).

5.2 Experience feedback on MRPP implementation

Since the process initiation in 1999, MRPP contributed to prevent several potential risky situations resulting from post-mining hazards.

In sensitive areas in term of surface occupation (high level of stakes, social pressure for urbanism development) the existence of disused mining works was not sufficient to limit or at least regulate urban development. One of the major advantages of a MRPP is that it makes possible to define rules that lead to organise city expansion. In the areas with low surface occupation, MRPP enables to formalise the knowledge related to the existence of disused mining works, which is often unknown by citizens, especially when the mine was closed down long time ago. MRPP allows thus to update and to synthesise the available data as well as a definition of urbanism rules in the sectors where the location of buildings is possible .

Other experience feedback has resulted from the many investigations performed.

- The hazard and risk assessment process is generally restricted to available data at present state of knowledge. This usually induces an over-estimation of the risk level (precaution principle), for example in defining hazard zoning in the areas where mining works are supposed to be present. This conservative approach is not always very easy to understand by local people. It presents however the advantage to define, for future surface developers, the investigations essential to enhance the knowledge on mining works and, thus, on remaining hazards.

- The existence of a precise mine closure applications (Didier et al., 1999) performed by the mining operators enhance considerably the state of knowledge. Hazard and risk evaluation and mapping are then much more precise and reliable, reducing by the way the extension of the sectors where the constraints have been defined only by presumption. Generally, such closure applications are only available for the recent mine abandonment.

- The PPRM planning has not always been optimal during the first implementation years. The choice of studied sites was, at first, mainly suggested by regional authorities, depending on the criteria that were not always felt pertinent. "Political pressure" has thus contributed to initiate studies in some areas with a very limited urban development. This has contributed to justify, for about 3 years now, the "Mining Sites Screening Process" (Didier at al., 2006). This global approach aims to analyse very rapidly about 3000 abandoned mining sites throughout France in order to hierarchise them regarding risk level. The process contributes thus actively to an efficient future MRPP integrating hazard and stakes criteria on the basis of priorities.

5.3 Further technical developments requested

Due to the lack of an operational methodology, "environmental hazard assessment" has, up to now, been reduced to strict minimum. Just few cases, with serious problems, have generated environmental hazard maps. Methodological tools and approaches are presently being developed. They will be operational in the coming years. Besides hazard assessment, one may also raise the question of the definition of regulatory principles related to those kinds of hazards.

Finally, the MRPP is definitely a multi-hazard and multi-risk tool (surface instability, gas emission, environmental impacts, flooding event, etc.). Indeed coupling and combining different phenomena is not an

easy task concerning hazard identification and characterisation. New scientific knowledge and technical tools are needed in this complex field.

The task appears to be even more complicated concerning transcription of multi-hazard phenomena in terms of regulatory measures. Some classical measures adapted to certain kind of hazard prevention have to be proscribed in case other hazard phenomenon may also develop at the same place. Flooding events and subsidence movements may thus contribute, for example, to prescribe incompatible measures for the design of building foundations.

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